ChE 456
Spring 2009
Major 2

Production of Ammonia

Background

Your company has been requested to complete a new design of an ammonia-from-syngas facility to replace the flawed design that you previously evaluated. The new plant capacity is 80,000 tonne/y, with an 8000-hour year.

Assignment

Your assignment is to provide a comprehensive process design for this new plant. Specifically, you are to prepare the following by 9:00 a.m., Monday, February 23, 2009:

1. Prepare a written report detailing your optimized process design for the new process subject to the constraints provided. The report should:

    - include a PFD that shows all the major equipment and process and utility streams. This PFD should be drawn using the standard icons in CorelDraw and should be legible, uncluttered, with all major equipment numbered, and all process streams identified by number. The PFD should be drawn in landscape format. Major control loops should also be drawn on the diagram.

    - include a flow table corresponding to the PFD requested above.

    - include a table with the design details (height, length, area, number of trays, power,, etc.) of all major equipment needed for the process.

    - include the utility requirements for all equipment. Results for utility costs should be presented either as a table or in a figure, but not both.

    - include the cost of manufacture for the process. Results for cost of manufacture should be presented either as a table or in a figure, but not both.

    - include the capital costs (grass roots) for all equipment. Results for capital costs should be presented either as a table or in a figure, but not both.

    - include an analysis of the economics for the project, using a basis of a 2-year construction period (60% first year, and 40% second year – land is already owned), a 10% after-tax rate of return, a 10-year operating life, and a taxation rate of 45%.

    - include a list of raw material costs for the plant.

2. An appendix should be included with its own table of contents. Page numbering may continue from the end of the report or it may restart. This appendix should include:

    a. a converged Chemcad report printed, using the output/report option, for your proposed design should be included in the Appendix. Do not include a full list of stream properties, but do include stream flows (mass and moles), unit operations, convergence results, and any other data relevant to your design.

    b. Excel spreadsheets for all capital cost estimations (using CACPCOST) and the cash flow diagrams.

    c. a legible, organized set of calculations justifying your recommendations, including any assumptions made. The appendices should have an accurate table of contents to allow the reader to find any particular calculation quickly.

Deliverables

Specifically, you are to deliver the following by 9:00 a.m., Monday, February 23, 2009:

1. Prepare a written report, conforming to the guidelines, detailing the information in items 1 and 2, above.

2. Attach a signed copy of the attached confidentiality statement.

Report Format

The written report is a very important part of the assignment. Reports that do not conform to the guidelines will receive severe deductions and will have to be rewritten to receive credit. Poorly written and/or organized written reports may also require rewriting. Be sure to follow the format outlined in the guidelines for written reports.

Oral Presentation

You will be expected to present and defend your results some time between February 23, 2009, and March 2, 2009. Your presentation should be 15-20 minutes, followed by about a 30-minute question and answer period. Make certain that you prepare for this presentation since it is an important part of your assignment. You should bring at least two hard copies of your slides to the presentation and to hand out before beginning the presentation.

Other Rules

You may not discuss this major with anyone other than the instructors. Discussion, collaboration, or any other interaction with anyone other than the instructors is prohibited.

Violators will be subject to the penalties and procedures outlined in the University Procedures for Handling Academic Dishonesty Cases (see p. 48 of 2007-09 Undergraduate Catalog or follow the link http://www.arc.wvu.edu/rightsa.html).

Consulting is available from the instructor. Chemcad consulting, *i.e.*, questions on how to use Chemcad, not how to interpret results, is unlimited and free, but only from the instructors. Each individual may receive five free minutes of consulting from the instructors. After five minutes of consulting, the rate is 2.5 points deducted for 15 minutes or any fraction of 15 minutes, on a cumulative basis. The initial 15-minute period includes the 5 minutes of free consulting.

Late Reports

Late reports are unacceptable. The following severe penalties will apply:

- late report on due date before noon: one letter grade (10 points)
- late report after noon on due date: two letter grades (20 points)
- late report one day late: three letter grades (30 points)
- each additional day late: 10 additional points per day

Appendix 1
Design Criteria for Unit 600

- Feed syngas
    - available from pipeline at a pressure of 1,000 kPa and ambient temperature
    - composition
        - 72 mol% hydrogen
        - 24 mol % nitrogen
        - 4 mol % of methane
        - 10 ppm carbon dioxide
- Maximum CO_2 allowed in reactor feed is 10 ppm. If CO_2 must be removed from process feed, monoethanolamine or diethanolamine (pure or dissolved in water) are recommended solvent candidates for a scrubber. The solvent can be recovered by stripping. These amines may require a non-typical materials of construction.
- Design basis = 80,000 tonne/yr of pure ammonia – this should be contained in the product stream – with an ammonia content >99.9 wt% as a liquid that can be pumped to a nearby rail loading facility.
- Selling price for ammonia is $500/tonne
- Cost of syngas is $0.10/kg
- Cost of monoethanolamine is $2.42/kg
- Cost of diethanolamine is $2.75/kg
- The Cost for the initial charge of catalyst is negligible.

Appendix 2
Information on Reactor and Reaction Kinetics

The only reaction of importance is

$$N_2 + 3H_2 = 2NH_3 \tag{1}$$

This reaction is reversible and is limited by equilibrium. The equilibrium expression is

$$K = \frac{p_{NH_3}^2}{p_{N_2} p_{H_2}^3} = 3.29 \times 10^{-12} \exp\left[\frac{11806}{T}\right] \tag{2}$$

where the pressure units are atm.

The kinetics are:

$$-r_{N_2} = k_f \frac{p_{N_2} p_{H_2}^{1.5}}{p_{NH_3}} - k_r \frac{p_{NH_3}}{p_{H_2}^{1.5}} \tag{3}$$

where

$$k_f = 5823 \exp\left[-\frac{17{,}307}{RT}\right] \tag{4}$$

and

$$k_r = 1.77 \times 10^{15} \exp\left[-\frac{40{,}765}{RT}\right] \tag{5}$$

where the rate units are kmol/m^{3}catalyst hr, the partial pressure is in atm, and the gas constant is in kcal/kmol. In Chemcad, chose the activation energy in kcal, the volume in m^3, the molar flow in kmol, the mass flow in kg, and the time unit of h. The catalyst is promoted iron oxide, with a specific gravity of 2.6 and a packing void fraction of 0.44. Remember that the required units in Chemcad for the reaction rate are kmol/m^{3}reactor hr.

You may wish to consider several reactor configurations. Some suggested configurations are shell-and-tube packed bed with heat removal, adiabatic reactor, and staged adiabatic packed beds with intercooling. There are other possibilities.